Author's Reply

Ronold W. P. King

The entire series of comments by Lapin and Guy deals with the specific absorption rate (SAR). That is, their comments are concerned with the temperature increase in the body due to microwave irradiation. Neither of the above papers[1,2] makes any claim that the microwave electric fields to which radio amateur operators are exposed have any significant thermal effect. The discussion in Section I of the above paper[2] shows that its concern was directed to the possible effect of microwave radiation on the replication of cells. Lapin and Guy should study the first two references in the above paper[2] (repeated here as [1], [2]). After they have studied them, they may not be quite so sure that "there is absolutely no basis for the conclusion that amateur radio operators are at any health risk." The effect of a microwave electric field on cells is quite different from thermal effects in the body.

References

[1] E. Pennisi, "Trigger for centrosome replication found," *Science*, vol. 283, pp. 770–771, Feb. 1999.

[2] E. H. Hinchcliffe, C. Li, E. A. Thompson, J. L. Maller, and G. Sluder, "Requirement of Cdk2-cyclin E activity for repeated centrosome reproduction in *Xenopus* egg extracts," *Science*, vol. 283, pp. 851–854, Feb. 1999.

Manuscript received December 21, 2000.

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Publisher Item Identifier S 0018-9480(01)02436-X.

[1]R. W. P. King, *IEEE Trans. Microwave Theory Tech.*, vol. 48, no. 9, pp. 1537–1543, Sept. 2000.

[2]R. W. P. King, *IEEE Trans. Microwave Theory Tech.*, vol. 48, no. 11, pp. 2155–2158, Nov. 2000.

Comments on "Electric Current and Electric Field Induced in a Human Body When Exposed to an Incident Electric Field Near the Resonant Frequency"

William B. Bridges

In the above paper,[1] King calculates the induced current density and electric field at the surface of a right circular cylinder modeling a human being in size and composition, when illuminated by a vertical dipole source 10-m distant with a power of 1 kW at 60 MHz. To quote from the abstract of the above paper: "Since this frequency range includes an important amateur radio band of 50–60 MHz and exposure to electric fields at this frequency has been shown to be hazardous, the study has a specific motivation." In his analysis, he derives a resonance curve for his model human that peaks at 53 MHz. At the conclusion of his paper, he gives the values of current density and electric field at the body for his assumed parameters and states: "These values are significant and provide a quantitative basis for the statistically observed increases in malignancies in amateur radio operators." This latter statement refers to a study by Milham [1] of mortality in a population consisting of men in California and Washington states that were listed by the Federal Communications Commission (FCC), Washington, DC, as possessing amateur radio licenses.

I will leave it to others to comment in detail on the merits of King's model and the actual biological effects of the current densities and electric fields he calculates with this model. However, I will make the following two observations on this matter: When using their transmitters, the great majority of radio amateurs will be seated at a desk typically covered with metal boxes. Whether such a seated person is well modeled as a right circular cylinder seems questionable to me. The second observation is that King cites only microwave studies on mice to show that electromagnetic radiation causes malignancies. Also, these studies themselves are widely disputed. He then uses simple dimensional scaling to show that 2.45 GHz for a mouse scales to 100 MHz for a man. Such a scaling law may be useful in calculating the "resonant frequency" for a human subject versus a mouse when treated as antennas, but such scaling is meaningless when the physics of a hypothetical carcinogenic process are unknown. Would 100 MHz be as effective as 2.45 GHz in causing cancer in a cell by this unknown process? In fact, there is no unequivocal evidence that radiation at either frequency causes cancer. Due to the variation of loss tangent with frequency, 2.45 GHz is much more effective in *cooking* tissue than 100 MHz so that this *known* process does not scale as King proposes.

However, my main objection to King's conclusions, quoted above in this paper's opening paragraph, is in the connection of his analysis to [1]. First, let us look at the Milham study. Milham obtained the names of 67 829 amateur radio license holders in the states of Washington and California from the FCC files whose licenses were in force from January 1, 1979 to June 16, 1984. The death records in these two states were then searched to obtain 2485 names matching those in the FCC file. The deaths were sorted into many standardized *International Classification of Diseases* (ICD-8) categories. A striking result of the study

Manuscript received December 12, 2000.

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Publisher Item Identifier S 0018-9480(01)02439-5.

[1]R. W. P. King, *IEEE Trans. Microwave Theory Tech.*, vol. 48, no. 9, pp. 1537–1543, Sept. 2000.

is that, for all causes, the 2485 deceased individuals had an overall mortality rate of 71% of the norm for the U.S. population as a whole. From this, you might conclude that holding an amateur license is definitely healthy! (Milham speculates that this is due to a lower rate of cigarette smoking among radio amateurs, but cites no statistics for this). Some of his categories also have lower than normal mortality rates: All circulatory diseases, all respiratory diseases, all accidents, all cancers (when grouped together) have mortality rates below 100% of the norm. However, two of the specific ICD categories had mortality rates exceeding the norm: Code 202 (other neoplasms of lymphoid tissue) and Code 203 (multiple myeloma) taken together had 43 deaths when only 26.6 would be expected in the normal population, for a mortality rate of 162% of the norm. Milham gives a $p < 0.05$ significance for this rate, implying a "one out of 20" probability that it is caused by chance alone. However, since Milham divided his original data into several different categories of cancer for analysis, it is much more likely than "one out of 20" that *at least one* category would exceed the norm by this much through chance alone. Thus, his 162% rate is not all that convincing about cause and effect. The proper conclusion from the Milham study would be that additional statistical studies of these cancers in larger or different populations of radio amateurs may be warranted. It is interesting that such studies were evidently not undertaken.

Next, let us consider some observations about amateur radio. The frequency range specifically cited by King, i.e., 50–60 MHz, does, indeed include a range assigned to radio amateurs. Before Wold War II (WW II), it was 56–60 MHz, i.e., the "5 meter band." In its infinite wisdom, the FCC changed this assignment to 50–54 MHz, i.e., the "6 meter band," following WW II in order to assign TV Channel 2 to 54–60 MHz, thus placing Channel 2 right on top of the harmonics from all the lower frequency amateur bands and creating endless grief for amateurs and TV viewers alike! Contrary to the impression given by King's statement that 50–60 MHz is ". . .a principal amateur-radio frequency. . .," the present 6-m band is arguably one of the least popular of all the amateur bands between 1.8–460 MHz. It is in only the last few years (a decade after Milham's mortality study) that this band has been included in the popular "made-in-Japan 100 Watt high-frequency transceiver" now used almost universally by amateurs. In the years before the Milham study, 5- or 6-m gear was home built and low power. It is likely that only a handful of amateurs the country possessed a 1-kW 6-m transmitter.

What is the impact of this on the Milham study? Milham could say nothing about the operating habits of the licensees he studied, beyond citing a survey of 8895 members of the American Radio Relay League in 1981 [2] that gave the "average amateur" as a 46 year-old male who was first licensed in 1963 and spent a total of 6.1 h a week on his hobby. Certainly nothing regarding whether or not the typical amateur used a 1-kW transmitter on 50 MHz. Thus, we are reduced to guess work about the operating habits of the individuals in the Milham study. You may make your own guesses; as an active radio amateur for 51 years (licensed 1949 as W6GEB, 1976 as W6FA), mine are as follows: 1% or fewer ever used 6 or 5 m, 0.1% or fewer used it as a significant part of their operating time, and fewer than 0.01% ever used 1 kW of power. If correct, this would put 678, 68, and 7 as the number of amateurs in the sampled population in these three categories. Thus, the overlap between King's physics and Milham's statistics seems nearly zero.

It is usually not worth the effort to comment on "unwarranted conclusions" in the technical literature. If the subject is unimportant, who cares? If the subject is important, further work will yield the truth. However, with a subject so "loaded" as electromagnetic radiation and human health, coupled with a tabloid press that exaggerates dangers, or even makes up new dangers, the possibility of a headline "Noted Harvard Professor Proves Amateur Radio Causes Cancer" cannot go unchallenged.

References

[1] S. Milham, Jr., "Increased mortality in amateur radio operators due to lymphatic and hematopoietic malignancies," *Amer. J. Epidemiol.*, vol. 127, no. 1, pp. 50–54, 1988.

[2] Amer. Radio Relay League, *Amateur Radio Survey 1980; A Look at Ham Radio as We Enter the Eighties*. Newington, CT: Amer. Radio Relay League, 1981.

Author's Reply

Ronold W. P. King

1) The claim that use is made of "simple dimensional scaling to show that 2.45 GHz for a mouse scales to 100 MHz for a man" is not correct. It is stated on the right-hand-side column of page 1537 of the above paper:[1] *"If scaling is assumed to be valid* according to the formulas $f_r h_r = f_m h_m$, $f_r a_r = f_m a_m$, where f is the frequency, h the half-length, and a the mean radius, these results could be significant for humans. Specifically, with $f_m = 100$ MHz, h_m, and a_m for a man, and f_r, h_r, and a_r for a rat or mouse, the frequency $f_r = 2450$ MHz gives $2h_r = 2h_m f_m / f_r = 100 \times 1.75/2450 = 0.071$ m or 7.1 cm. This is a reasonable length for a rat or mouse. The validity of such scaling is examined as part of this study." Later, on page 1540 at the end of Section IV of the above paper, it is stated: "An examination of (3) for z^i and (27) for $J_{1z}(\rho, z)$ shows that the radius a occurs in a^2 and in $k_1 a$, not only as $k_2 a$ as required for frequency scaling. It follows that *scaling as described in the introduction and as used by Gandhi [21] is not quantitatively valid in the frequency range 50–200 MHz.*"
2) The author is grateful to Dr. Bridges for his detailed information about the Milham study. Actually, it is irrelevant to the analytical determination of the electric fields and currents induced in the human body in the 50–200-MHz range. It seemed to provide an additional motivation for studying this range. However, the facts should have been looked into more closely or the reference omitted. Actually, in the more recent detailed study in [1], no mention is made of the Milham study until the very last sentence where it is stated: "Although no direct correlation is possible, the fact that statistical evidence found by Milham [17] indicates an increase in malignancies in some radio amateur operators over that of the general population should not be ignored."
3) Dr. Bridges' detailed information about frequencies used by amateur radio operators is interesting, but not particularly important with reference to the complete analysis in [1] of one actual amateur radio setup. Reference [1] provides detailed formulas

Manuscript received December 21, 2000.

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Publisher Item Identifier S 0018-9480(01)02435-8.

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